Notes on the operation of MHATT-CAT High Heat load Monochromator

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Abstract

This is a short update of the High Heat Load Monochromator (HHLM) performance at MHATT-CAT showing the expected flux, beam size and stability of the device to date. I wished to have this a little more detailed than it is now, but some computing constraints have forced me to cut it to the essential for now. The appendices also includes some useful calculations on the beam size and source size at 7ID for the current APS operation mode with a 1% vertical coupling, and discuss the time structure of the APS beam.

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FIGURES

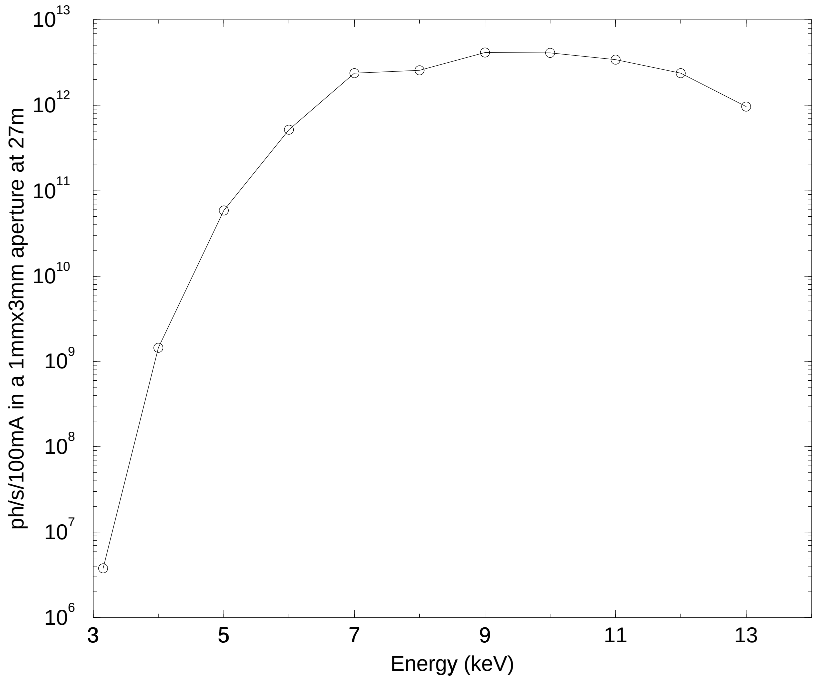

FIG. 1. Total monochromatic flux in a 3 mm (horizontal) by 1 mm (vertical) acceptance at 27 m versus Energy.

During the tail end of the commissioning of the Kappa goniometer in 7ID-C, I collected a few numbers which may be interesting for the MHATT-CAT community. The experiment described below used the HHLM which is placed 30 m from the source, and the white beam slits placed 27 m from the source both situated in the 7ID-A hutch, the optical enclosure. An ion chamber filled with N_2 was mounted at the end of the exit window of the Micro-Mono in 7ID-B, 35 m from the source to accept all the monochromatic flux.

Fig. 1 shows the total monochromatic flux versus energy for the High Heat Load monochromator. This data was obtained by centering the white beam slits on the center of the white beam, and calibrating their opening to 3 mm by 1 mm. The opening of the white beam slits was on the generous side to catch nearly all the flux. Scanning either one jaw of the white beam slits in the beam and taking the derivative, or scanning two jaws simultaneously with a fixed opening, one can measure the beam profile at the slits position. Although these data are not shown here, the results show that the FWHM of the beam in the horizontal and vertical is respectively 1.5 mm and 0.33 mm at the white beam slits position (27 m). This measurement compares fairly well with a calculation in the appendix of 1.6 mm and 0.41mm. The maximum flux measured during this run (4.15×10^{12}ph/s/100mA at 9 keV) is more than a factor 3 less than the flux measured last April 15, 1999 (1.54×10^{13}ph/s/100 mA at 9.5 keV) during the last monochromator run. The previous measurement was done in air and with a different ion chamber, and it is possible that the large drop is due to the lack of reproducibility of measuring total flux with an ion chamber.

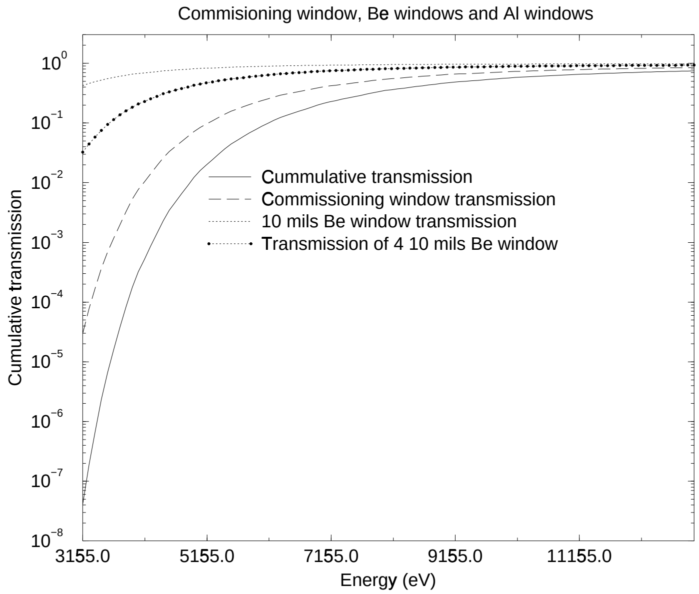

FIG. 2. Transmission of windows versus energy. The cumulative transmission is shown, as well as the transmission of the commissioning window alone, of a single Be window, and of four Be windows.

The drop in flux on the low energy side is caused by the absorption of windows due to the presence of a commissioning window (two 10 mils Be windows and 498 μm of graphite) and four 10 mils thick Be windows which suppress the low energy spectrum. For reference, Fig. 2 shows the cumulative transmission of all the windows on 7ID. These windows reduce the intensity by a appreciable factor 3 at 8 keV and 5 at 7 keV. Most of the losses at low energy are due to the presence of the commissioning window, specifically the graphite and CVD diamond in the assembly, present to reduce the power load in the downstream Be windows. Experiments at low energies on 7ID with the High Heat Load Monochromator would have a poor flux at the moment.

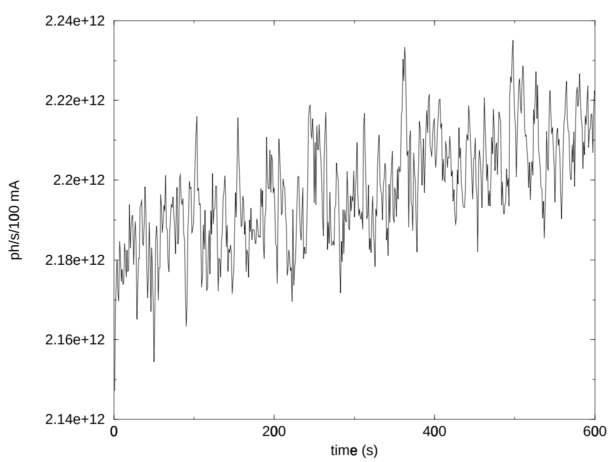

FIG. 3. Time series of the ion chamber signal at 9 keV.

Fig. 3 shows the short time scale stability of the monochromatic flux. Over ten minutes, the intensity showed rms fluctuation of 0.6 %, which is quite good. The slight baseline increase was due to the monochromator's readjusting its temperature after the gap was reopened before this measurement.

Over longer periods of operation, the intensity will suddenly drop during a fill of the low-pressure circuit of the crycooler. The cryocooler needs to refill its low-pressure dewar every few hours (2-3) depending on the heat load accepted by the monochromator. From our previous experience during last year's commissioning activities, we found that the total flux decay is proportional to the beam current decay during the fill.

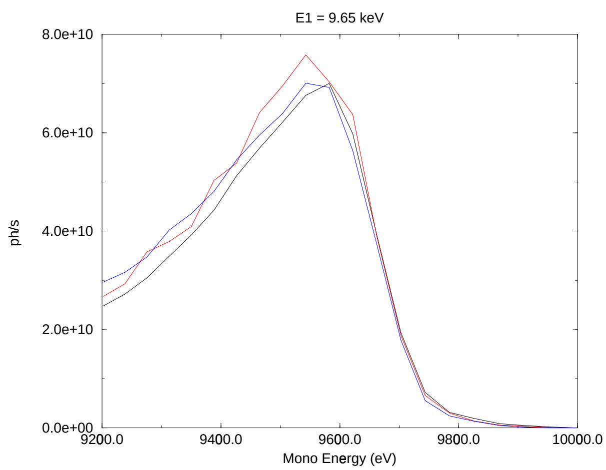

FIG. 4. Three scans of the energy of the monochromator.

Regarding the energy scannability of the device, a typical energy scan of the monochromator at 9.65 keV is shown in Fig. 4. The reproducibility has improved from our initial commissioning activities of last year, but it becomes far worse at lower energies (not shown).

I hope the above data will be helpful in planning experiments at 7-ID. Experiments above 7 keV will utilize a large fraction of the brilliance of the source. Find below some calculation on the beam parameters.

APPENDIX A: SOURCE SIZES, DIVERGENCES AND BEAM PROFILE AT 27 M

These calculations will assume that we close the white beam slits (L5-20) placed about 27 m from the source to an opening of 4σ which passes 95.5 % of the flux of the undulator fundamental to reduce the total power absorbed in the monochromator placed 30 m from the source.

The horizontal emittance of the APS is currently approximately $\epsilon_x = 7.0 \pm 0.8$nm rad, and the vertical coupling is about 1 % [1]. The low β_y lattice has now parameters of $\beta_x = 14.7$m and $\beta_y = 5.1$m [1]. From the emittance and beta function, the rms horizontal (x) and vertical (y) source sizes are [2]

$$\sigma_{x,y} = \sqrt{\epsilon_{x,y}\beta_{x,y}} \; , \tag{A1}$$

and the rms source divergences are

$$\sigma_{x',y'} = \sqrt{\epsilon_{x,y}/\beta_{x,y}}\ . \tag{A2}$$

Replacing the current emittance and beta functions in Eq. A1 and A2, one finds that the electron beam rms source sizes and divergences are $\sigma_x = 321\mu\mathrm{m}$, $\sigma_y = 18.9\mu\mathrm{m}$, $\sigma_{x'} = 21.8\mu\mathrm{rad}$ and $\sigma_{y'} = 3.7\mu\mathrm{rad}$.

The total X-ray beam divergences are

$$\Sigma_{x',y'} = \sqrt{\sigma^2_{x',y'} + \sigma^2_{r'}}, \tag{A3}$$

where $\sigma_{r'} = \sqrt{0.5\lambda/L}$ is the single electron natural divergence of an undulator of total length $L = 2.4\mathrm{m}$ at a given wavelength λ [2].

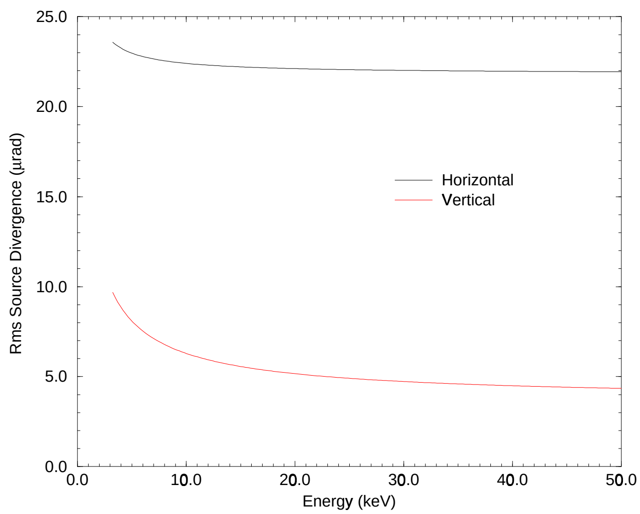

FIG. 5. X-ray beam rms source divergences versus energy.

Fig. 5 shows the energy dependence of the source divergence in the horizontal and vertical direction. The energy dependence must be accounted for since the variation can be appreciable, especially in the vertical direction.

Similarly, the total rms source size is

$$\Sigma_{x,y} = \sqrt{\sigma^2_{x,y} + \sigma^2_{r}}, \tag{A4}$$

where the single electron source size is $\sigma_r = 0.25\sqrt{2\lambda L}/\pi$ [2].

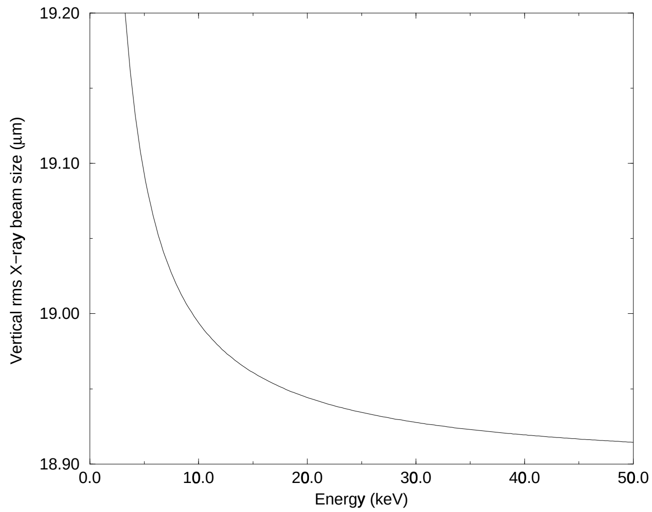

FIG. 6. Vertical X-ray beam rms source size versus energy.

Fig. 6 shows the X-ray beam vertical rms source size which varies weakly (less than 1.5%) over the energy range shown. The X-ray beam horizontal rms source size (320.8 μm) is not shown since it changes by only by 44 ppm over the range of energies shown.

From these source sizes, one can also compile the transverse coherence of the source given by

$$l_{x,y} = \frac{\lambda R_e}{2\sqrt{\pi}\Sigma_{x,y}}, \tag{A5}$$

where $R_e \approx 35$m is the distance source-experiment for ID-B. Eq. A5 takes into account the Gaussian source profile into the computation of the transverse coherence length [3].

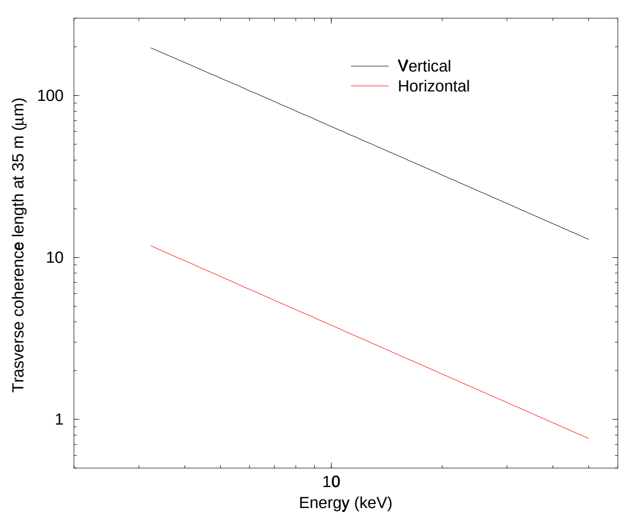

FIG. 7. X-ray transverse coherence lengths, 35 m from the source.

Fig. 7 shows the transverse coherence lengths in the horizontal and vertical in ID-B. The X-ray beam size at a given distance R_s from the source is thus

$$\Sigma^*_{x,y} = \sqrt{\Sigma^2_{x,y} + R_s^2 \Sigma^2_{x',y'}}. \tag{A6}$$

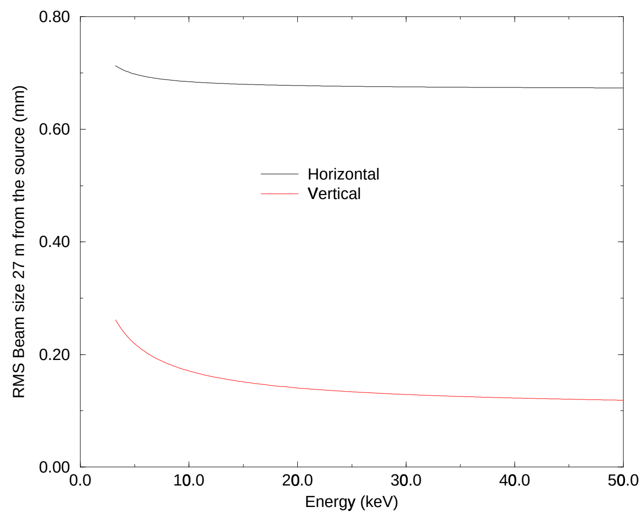

FIG. 8. X-ray beam rms size at 27 m from the source.

Fig. 8 shows the rms beam size at the L5-20 slits position, 27 m from the source. At 9 keV, the rms spot size is 0.175 mm and 0.68 mm, thus one expects the FWHM to be 0.41 mm and 1.60 mm respectively in the vertical and horizontal direction. These estimates are consistent with our measurements of 0.33 mm and 1.5 mm at 9 keV.

APPENDIX B: TIMING STRUCTURE

Regarding timing experiments, currently the APS is running in singlet mode, which means that 22 bunches are carrying the current (if we ignore for simplicity the 6 buckets at the beginning used for Beam Position Monitors). These 22 bunches are separated by 150 ns, thus the average number of photon per bunch will be 150ns$\times 4 \times 10^{12}$ph/s = 600 000 ph/bunch. The bunch is supposed to have a 30 ps rms Gaussian standard deviation.

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